APPENDIX A

Stromatolites And Other Organic Remains In The Bangemall Basin

by

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INTRODUCTION

A study of fossil material from the Bangemall Basin was undertaken in an attempt to assess the palaeoecological and biostratigraphical potential of stromatolites and other organic remains. Stromatolites are abundant in the dolomitic carbonates of the Bangemall Group, although their taxonomic diversity is low (Grey, 1982). They are present in the lower part of the succession in the western and northern facies, and are particularly common in the Irregully Formation. They also occur in the Top Camp Dolomite, Kiangi Creek Formation and Devil Creek Formation. A stromatolitic dolomite is present near the top of the Skates Hills Formation, a basal unit of the eastern facies. Isolated stromatolitic outcrops of possible Bangemall Group are known from the Gascoyne Province.

Poorly preserved organic material occurs in chert and silicified siltstone in several formations. Various structures of possible organic origin, now altered to such an extent that their original nature is difficult to determine, are present in many samples, especially in the Coobarra Formation, Irregully Formation, Kiangi Creek Formation, Jillawarra Formation, Discovery Chert, Fords Creek Shale and Backdoor Formation. Abundant amorphous carbon of probable organic origin was released by maceration of some samples in hydrofluoric acid, and spheroids of uncertain origin have been obtained from a few samples. A fairly diverse assemblage could possibly be obtained by more selective sampling. However, contamination cannot be ruled out for these samples (Cloud and Morrison, 1979), and the results reported here should be regarded as a preliminary indication of areas in which more rigorous studies could be carried out.

Possible calcareous chlorophytes from the Devil Creek Formation and discoid megafossils from the Irregully Formation were described by Marshall (1968). No similar material was found during the present study.

PREVIOUS STUDIES

A history of stromatolite studies is given by Walter (1972), and by several authors in Walter (1976). The presence of stromatolites in the Bangemall Group seems to have gone unnoticed until systematic regional mapping was undertaken by the Geological Survey. They are first recorded by Halligan and Daniels (1964) and figured by Daniels (1966).

Preliminary results of biostratigraphic studies of stromatolites in Australia (including some from the Bangemall Basin) were published by Glaessner and others (1969). In 1972, Walter published the first systematic studies of Bangemall stromatolites. Further studies (Grey, 1977a; 1978a) on the Bangemall Group have now been carried out. The biostratigraphic distribution of stromatolites in the Bangemall Basin and their relationships to other stromatolite occurrences in Western Australia are discussed by Grey (1979; 1982). Possible Bangemall Group outliers containing stromatolites have also been reported (Grey, 1977b; van de Graaff and others, 1977).

Microfossils were first discovered in the Bangemall Group by J. Schupp (Daniels, 1975) and were studied by Marshall (1968). Marshall noted the presence of abundant acritarchs in the Irregully Formation, the Jillawarra Formation, and the Discovery Chert. He concluded that the acritarchs were of probable planktonic origin because of their wide distribution.

Marshall (1968) also reported the presence of discoid megafossils of possible medusoid affinities in the Irregully Formation. In addition, he recorded several types of calcareous microfossils from the Devil Creek Formation, which he believed showed affinities with complex chlorophytes. Marshall's localities were not revisited during the present studies, but a brief examination was made of his original material, which is housed in the Princeton University collection.

Marshall's findings suggested the presence of organisms of much greater complexity than are generally believed to have existed at this time (Schopf and others, 1973). However, some of the specimens show a striking resemblance to *Microcodium* described by Esteban (1974) from an Eocene caliche from Spain, and are of doubtful Proterozoic age. The structures described as medusoids by Marshall are most probably of non-biogenic origin and may well be derived from gypsum rosettes. Other samples contain concentrically-banded, oval structures of considerable morphological complexity. These appear to be biogenic and more detailed examination is required to determine their nature. The significance of the Bangemall Group structures is therefore uncertain. No evidence of similar material was observed in the GSWA collection.

METHODS OF STUDY

Stromatolite samples were collected from approximately 60 localities, either by the author, or by members of the Bangemall Basin mapping parties. Methods of study, both field and laboratory, are basically those outlined by Walter (1972) and Preiss (1976a.)

The literature on stromatolitic carbonates is extensive, two recently published books (Ginsburg, 1975; Walter, 1976) present comprehensive reviews of various aspects of the subject, and a two-part bibliography has been published (Awramik and others, 1976; Awramik and others, 1979).

In addition to the study of stromatolites, 87 cherts, silicified shales and other silicified rocks were examined in thin section to determine their organic content and selected samples were macerated with hydrofluoric acid. Few samples were collected specifically for palaeontological examination, and better preserved material could probably be obtained by more selective sampling.

PRESERVATION AND COMPOSITION OF THE BIOTA

Stromatolites and other organic remains occur mainly in the western part of the Bangemall Basin and are mostly absent from the more arenaceous facies to the east, with the exception of a carbonate unit in the Skates Hills Formation. Stromatolites are most common in the Irregully Formation and its lateral equivalents. Although stromatolites are numerically abundant, their taxonomic diversity is low (Grey, 1982). Many are stratiform or domed and are of little value for stratigraphic purposes. Poor preservation and extensive silicification, particularly along the western margins of the basin, prevents the identification of many branching columnar forms.

Baicalia capricornia Walter (Fig. 113) is the most common of the branching columnar forms and is present throughout the Irregully Formation, and ranges upwards into the Devil Creek Formation. It is also present in the Kiangi Creek Formation, and has recently been collected from the Mulya Dolomite in the adjacent Gascoyne Province. *Conophyton garganicum australe* Walter (Fig. 114) occurs in the lower part of the Irregully Formation and in the Top Camp Dolomite.

Conical structures are present along the western margin of the basin but they are poorly preserved and highly silicified. Although they were originally considered to be forms of *Conophyton*, (Grey, 1979; 1982) more recent investigations, particularly of those occurring in the Milly Springs area, suggest that some of them are tepee structures, while others are draped stromatolitic structures similar to those described by Vlasov (1977).

A new stromatolite form, consisting of straight, unbranched, club-shaped columns (Figs 115 and 116), was collected from the middle part of the Irregully Formation in Irregully Gorge, but has not yet been described. Poorly preserved *Conophyton garganicum australe* occurs in a possible Bangemall outlier near Hectors Bore (Grey, 1977b).

Acaceilla cf. *australica* occurs in the Skates Hills Formation (Grey, 1978a), which crops out on the eastern margin of the basin.

Amorphous carbon of probable organic origin, and poorly preserved structures of doubtful organic origin, are present in the Coobarra Formation, Irregully Formation, Kiangi Creek Formation, Jillawarra Formation, Discovery Chert, Ullawarra Formation, Fords Creek Shale, and the Backdoor Formation. Marshall (1968) reported the occurrence of acritarchs in the Irregully, Jillawarra, Discovery Chert, and Devil Creek Formations. None of the material examined in this study seems to be as well-preserved as that described by Marshall. In many of the samples the carbonaceous material occurs as minute particles which are either finely disseminated throughout the sample, or are concentrated along crystal boundaries. In some samples opaque spheres are present, but they are usually poorly preserved and have diffuse boundaries indicating recrystallization. Most of these spheres range in size from 5-8 μm but larger, very diffuse spheres up to 30 μm are also present.

Although no identifiable microfossils are present in any of the thin sections examined, some problematic structures occur which are believed to have developed from original organic material. These include grey or brown spheres with radiating or concentric structures, (Fig. 117a), trails of diffuse carbonaceous material (Fig. 117B), and 'pods' of coarse silica crystals (Fig. 117C), which are bounded by concentrations of organic material, and in which each quartz grain has an opaque carbonaceous spheroid at its centre. These pods may have developed as a result of the differential crystallization of silica around microbial filaments, similar to those described from the Waterton Formation by Oehler (1976). In the specimens from the Bangemall Group, recrystallization has progressed further than that described from the Waterton Formation. Organic material has moved along the front of crystallization to form a structure which has 'walls' and contains spore-like bodies.

In some samples, spheres and cubes of iron oxide are present. These occasionally occur linked in chains and have a similar mode of preservation to material in the 1 500 m.y. old H.Y.C. Pyritic Shale Member of the Barney Creek Formation in the McArthur Group of northern Australia (Oehler, 1977).

Problematic tubular structures with terminal spheroids (Fig. 117D-F) are abundant in a sample from the Discovery Chert (Grey, 1978b). M. R. Walter (pers. comm.) pointed out their resemblance to the trails of ambient pyrite grains (Tyler and Barghoorn, 1963; Knoll and Barghoorn, 1974). Although the Discovery Chert structures have some features in common with ambient grain trails, they exhibit several puzzling features, and the origin of the structures remains doubtful (Grey, 1978b).

Selected samples from several formations were macerated, and in most cases the residues were found to contain abundant amorphous carbon. Some samples from the Discovery Chert, and in particular from the Backdoor Formation, contain organic material of spheroidal or oval shape (Fig. 117G-I), some of which have thick walls and granular to reticulate ornament. Some specimens show budding and others occur as diads or tetrads. The affinities of these micro-organisms have not been determined, and, as has already been discussed, it is possible that these structures are contaminants. They are however, recovered in great abundance in some samples, and this suggests that further investigation should be carried out.

STRATIGRAPHIC DISTRIBUTION

COOBARRA FORMATION

A single specimen of brown chert with abundant silica spheres contained finely disseminated carbon particles and small opaque spheres. 'Pod' structures are common.

IRREGULLY FORMATION

The Irregully Formation, a major carbonate unit in the western facies of the Bangemall Basin contains abundant stromatolitic beds, particularly in the Parry Range, Henry River and Irregully Creek areas.

Stromatolites are common in the carbonates of the Parry Range area, but preservation is usually poor, due to considerable alteration and surface silicification. At many localities, only the overall shape and broad banding remain to indicate an original stromatolitic origin. At some localities silicified bands occur in close proximity to unaltered carbonate and laminae can be traced across the boundary. Few laminae are preserved where silicification has occurred. Instead, the silicified portions of the stromatolites contain broad bands which apparently follow the original laminations, but which terminate in sharp crests. The reasons for the difference between the two lithologies is not clear, but some of the V-shaped terminations may be of secondary origin, and are probably tepee structures. Others may resemble the stromatolitic structures described by Vlasov (1977).

Columnar and cone-shaped stromatolites may be present at some localities, but because of poor preservation it is difficult to distinguish them from forms with a crested or V-shaped termination, or from deformation structures. In the northern Parry Range area identification of the columnar forms is not possible. Very little can be determined about the environment of deposition, other than to suggest that it was most probably intertidal.

In the southern part of the Parry Range there is greater development of columnar and conical forms although deformation and silicification are also noticeable in this area. Extensive outcrops occur in the vicinity of Wongida Well and Milly Springs and require more detailed study. Silicification in this area has destroyed many details of lamination, making identification difficult. In particular, it has not been possible to make a detailed study of crested and V-shaped forms which occur in this area. Club-shaped columnar stromatolites, resembling an undescribed form from Irregully Gorge, are found in unsilicified carbonate.

In the Milly Springs area there is an apparent development of cyclic sequences comprising a basal unit of intraclastic or, more rarely, a possibly oncolitic dolomite, overlain by a dark blue-grey limestone containing club-shaped, columnar stromatolites. This passes upwards into a silicified unit containing flat-laminated and crested stromatolitic banding. Similar association of stromatolite-rich sequences have been described from the Proterozoic of the Canadian Shield (Hoffman, 1976) but further studies are necessary before more detailed comparisons can be made between the Irregully Formation and the cycles described by Hoffman.

The columnar stromatolites most probably formed in quiet water, lagoonal conditions, while the silicified, crested stromatolites may indicate a shallow-water intertidal to possibly supratidal phase.

The type locality of *Baicalia capricornia* Walter, is an extensive outcrop near the Henry River East Branch. *Baicalia capricornia* also occurs in a second outcrop near the type locality, and at an outcrop near Pindanni Bore, although preservation at these localities is poorer than at the type locality. Stromatolite formation occurred in a series of overlapping bioherms, probably in shallow subtidal or lagoonal environments. Other outcrops in this general area contain only poorly preserved, non-columnar types.

Approximately 1 300 m of Irregully Formation is exposed at Irregully Gorge and upstream of the gorge along the banks of Irregully Creek. Much of the succession is stromatolitic. Preservation is remarkably good in some parts of the gorge, and this area would merit further study.

Walter (1972) recorded *Conophyton garganicum australe* and *Baicalia capricornia* from near the base of the Irregully Formation at the north end of the gorge. Flat-laminated, undulatory and pseudocolumnar forms occur commonly throughout the sequence; and, at the southern end of the gorge, an unnamed form with unbranched, club-shaped columns occurs. *Baicalia capricornia* is present near the top of the Irregully Formation in the vicinity of the White Cliffs.

A somewhat variable environment of deposition is indicated. Flat-laminated stromatolitic banding probably indicates upper intertidal to supratidal conditions while *Baicalia capricornia* probably grew in moderately high-energy conditions in the shallow subtidal to intertidal regime. Deeper water and quieter conditions are indicated by the presence of *Conophyton garganicum australe* and the club-shaped form.

Miscellaneous outcrops of stromatolites in the Irregully Formation occur at Coolinbar Hill, near Peedawarra Flats, and on Mulgul and Woodlands stations. Some of these localities have columnar forms, which can be tentatively identified as *Baicalia capricornia* Walter, and show evidence of fairly high-energy conditions at the time of deposition since interspace filling frequently consists of platey intraclasts, often stromatolitic in origin. Other stromatolites are either non-columnar or too poorly preserved to allow identification. A shallow, subtidal to intertidal environment, probably with a moderately high-energy regime is indicated.

The discoid megafossils of possible medusoid affinity reported by Marshall (1968) were collected from a locality in the Irregully Formation 27.2 km south-southwest of Ashburton Downs homestead. This locality was not examined in the present study and no comparative material was found elsewhere.

Two samples of chert from the Irregully Formation contained finely disseminated carbon particles, but no identifiable microfossils. Marshall (1968) reported the presence of acritarchs, but only rare, poorly preserved opaque spheres were observed in the present study. Spheres and cubes of iron oxide are also present.

KIANGI CREEK FORMATION

Only one stromatolite locality has been reported from this formation and this contains a columnar form tentatively identified as *Baicalia capricornia*. A single chert sample contains abundant, finely disseminated carbon particles, but no identifiable microfossils.

JILLAWARRA FORMATION

Samples from this formation contain abundant, finely disseminated carbon particles and, occasionally, poorly-preserved, opaque spheres with an average diameter of 6 μm. Cubes and spheres of iron oxide, which may have replaced organic material, are also present.

DISCOVERY CHERT

Many of the samples examined from this formation have undergone considerable recrystallization, and although abundant amorphous carbon is present in most samples, no identifiable microfossils were observed in thin section. The carbon particles may be either finely disseminated throughout the sample, or concentrated around crystal boundaries. In some samples the carbon is concentrated in lenses. Small, dark spheres, often showing concentric or radiating structures indicative of recrystallization, are sometimes present. Iron oxide particles, sometimes in the shape of spheres and cubes, which are possibly replacing organic material, are common and may be linked together in chains. Elongate 'pods' are common in some samples. Some poorly laminated brown cherts contain large patches of fine-grained, brown material concentrated in spheres which may be similar to the elongate pod-shaped structures in black cherts.

A sample from near Coobarra Creek contains tubular structures of uncertain origin resembling ambient pyrite grains. Laminated structures resembling stromatolites occur in one or two samples, but the laminae are more regular than is usual for stromatolites, and they are composed of clay particles, suggesting an inorganic origin. Abundant amorphous carbon, and spheroids of variable size, ranging up to 16 μm in diameter were recovered by maceration from brown chert. The affinities of these spheres have not been determined and the possibility of contamination cannot be ruled out.

DEVIL CREEK FORMATION

Only one stromatolite locality with *Baicalia capricornia* has been recorded from the Devil Creek Formation, a locality near White Cliffs in Irregully Creek. Marshall (1968) reported calcareous microfossils in the Devil Creek Formation, at a locality near Cobra homestead, and from two other localities where material is poorly preserved. Several different types of microstructure are present and Marshall suggested that they showed affinities with structurally complex chlorophytes. Marshall's localities were not visited during the present study, and no similar material was collected from other localities.

ULLAWARRA FORMATION

Samples from this formation were strongly recrystallized and contained no evidence of organic material, with the exception of a single chert sample containing abundant amorphous carbon.

FORDS CREEK SHALE

A fine-grained, laminated, brown chert was examined and found to contain diffuse carbon particles and small dark spheres of possible biogenic origin. Iron oxide spheres, and chains of spheres also occur. Laminations in the chert are wavy-banded and have the typical alternating light and dark banding associated with stromatolites.

TOP CAMP DOLOMITE

Stromatolites have been recorded from Fords Creek (Daniels, 1968; Walter, 1972) and from near Pingandy Creek. At Fords Creek *Conophyton garganicum australe* Walter occurs about 40 m above the base of the succession in the Tchintaby Dolomite Member. Very large forms of *Conophyton garganicum australe* occur in a dolomite unit of uncertain stratigraphic position between the Bearuroo Dolomite Member and the Pingandy Dolomite Member near Pingandy Creek.

An extensive outcrop of large conical forms is found at this locality, probably representing a series of bioherms, consisting of several successive layers of cones with an average maximum observed diameter of 4 m.

Following Donaldson's (1976) suggestion for calculating the relief of individual cones the minimum relief of the Pingandy specimens would have ranged from 3 m to 9 m. Donaldson suggests that the formation of such large cones could only have occurred in quiet, relatively deep-water conditions by bacterial precipitation. At Irregully Creek and Fords Creek, the specimens are smaller than at Pingandy Creek, and the water depth may have been correspondingly shallower.

Other stromatolite localities in the Top Camp Dolomite contain only flat-laminated or domed forms.

BACKDOOR FORMATION

Samples of the Backdoor Formation consist of a fine-grained, poorly laminated, brownish chert containing abundant spheres with a high birefringence, probably jarosite. Reddish-brown and dark-grey spheres are also present, and may be of organic origin, but this cannot be demonstrated in thin section.

Abundant acritarchs of uncertain affinities were obtained by maceration. They consist of spheroids and ovoids of variable size and shape. A large number of spheriods are from 6-10 μm in diameter, but others may be up to 30 μm in diameter. Most specimens have thick walls and may have granular to reticulate ornament. The acritarchs may occur singly or in groups. Some spheres have been broken, and appear hollow. These structures may well be contaminants (Cloud and Morrison, 1979).

SKATES HILLS FORMATION

A stromatolitic dolomite occurs near the top of the Skates Hills Formation, a basal unit of the Bangemall Group in the eastern facies, (Williams and others, 1976). Specimens from two localities consist of extremely well-preserved columns of *Acaciella* cf. *australica* (Grey, 1978a). Specimens from a third locality consist of cumulate forms, which may be basal portions of the columnar forms, but which are not sufficiently developed for accurate determination. A moderately high-energy environment of deposition is indicated by the lateral elongation of the columns in one of the samples to form structures resembling ripple marks.

PROBABLE BANGEMALL GROUP OUTLIERS

An outlier of probable Bangemall Group occurs near Hectors Bore on GLENBURGH (Williams and others, 1980), and contains *Conophyton* and stratiform stromatolites (Grey, 1977b) with some development of tepee structures. Preservation of the *Conophyton* is too poor for the form to be determined, but it has affinities with *Conophyton garganicum australe*.

In the Uaroo Group, to the west of the Bangemall Basin in the Yanrey area, the Mulya Dolomite and the Tinkers Dolomite have both been described as algal dolomites (van de Graaff and others, 1977). Deformed and silicified bioherms of

Baicalia capricornia are present in the Mulya Dolomite supporting a possible correlation between the Uaroo Group and the Bangemall Group (van de Graaff and others, 1977).

BIOSTRATIGRAPHY

Grey (1979, 1982) has summarized the data on biostratigraphic relationships of stromatolites in Western Australia. *Baicalia capricornia* and *Conophyton garganicum and australe* are known only from the Bangemall Group. The group *Baicalia* has a range from 1 350 to ?900 m.y. (Preiss, 1976) while *Conophyton* occurs in the late Archaean and throughout the Proterozoic and in early Cambrian (Krylov and Semikhatov, 1976). However, the form *Conophyton garganicum* is thought to be restricted to the period from 1 600 m.y. to about 1 000 m.y.

The previously known range of *Acaciella* is from less than 1 000 m.y. to early Cambrian (Preiss, 1976). *Acaciella* cf. *australica* from the Skates Hills Formation is probably older than this (Grey, 1978a) however, the age of the Skates Hills Formation is uncertain, although it is correlated with rocks younger than the 1 100 m.y. stromatolitic sequence in the western part of the Bangemall Basin (Williams and others, 1976).

The potential of microfossils for biostratigraphy is still a matter for debate although several important trends have been recognized in recent years (Schopf, 1977). The poor preservation and possible contaminant origin of the Bangemall Group material makes detailed comparisons with other assemblages difficult, and no conclusions are possible at present.

CONCLUSIONS

Stromatolites are abundant in the western part of the Bangemall Basin and probably played an important role in the deposition of the lower part of the Bangemall Group. Taxonomic diversity is low and the forms present are known only from the Bangemall Basin and outliers of probable Bangemall age. The environment of deposition was mainly shallow subtidal to intertidal. Poorly preserved material of possibly biogenic origin is present in cherty sediments in the Bangemall Group. Better preserved material could probably be obtained by more selective sampling, and the present results are inconclusive because of possible contamination.

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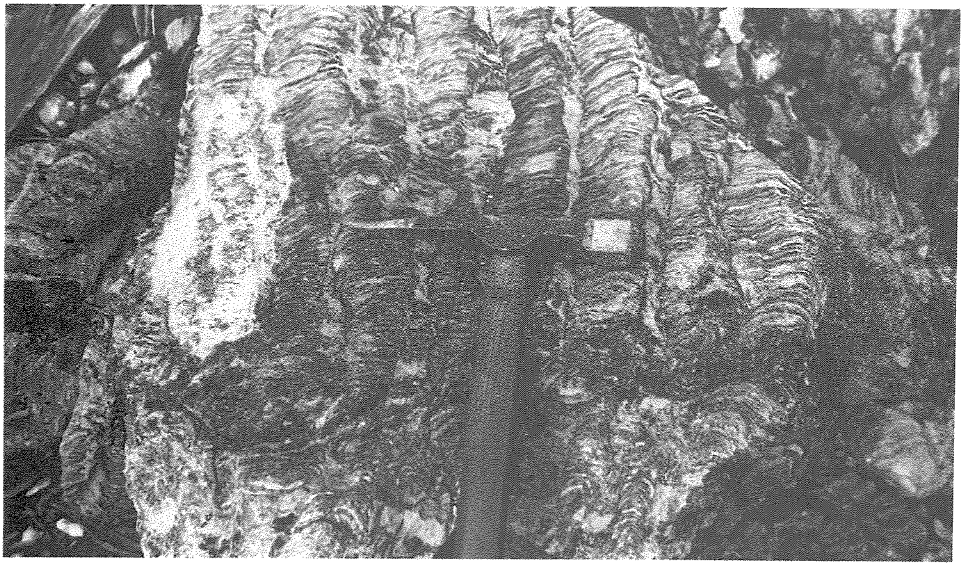
Figure 113. *Baicalia capricornia* Walter. A—Specimen at type locality. B—GSWA F9908 from the type locality.



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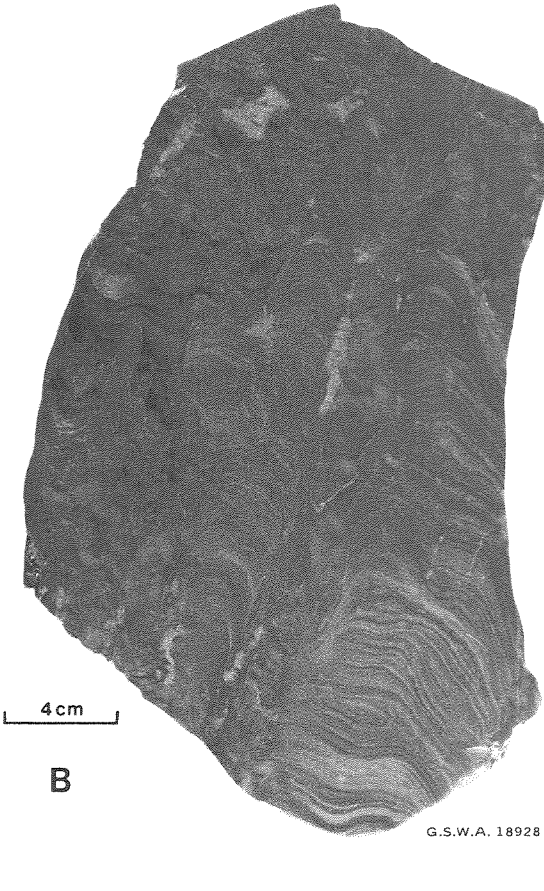
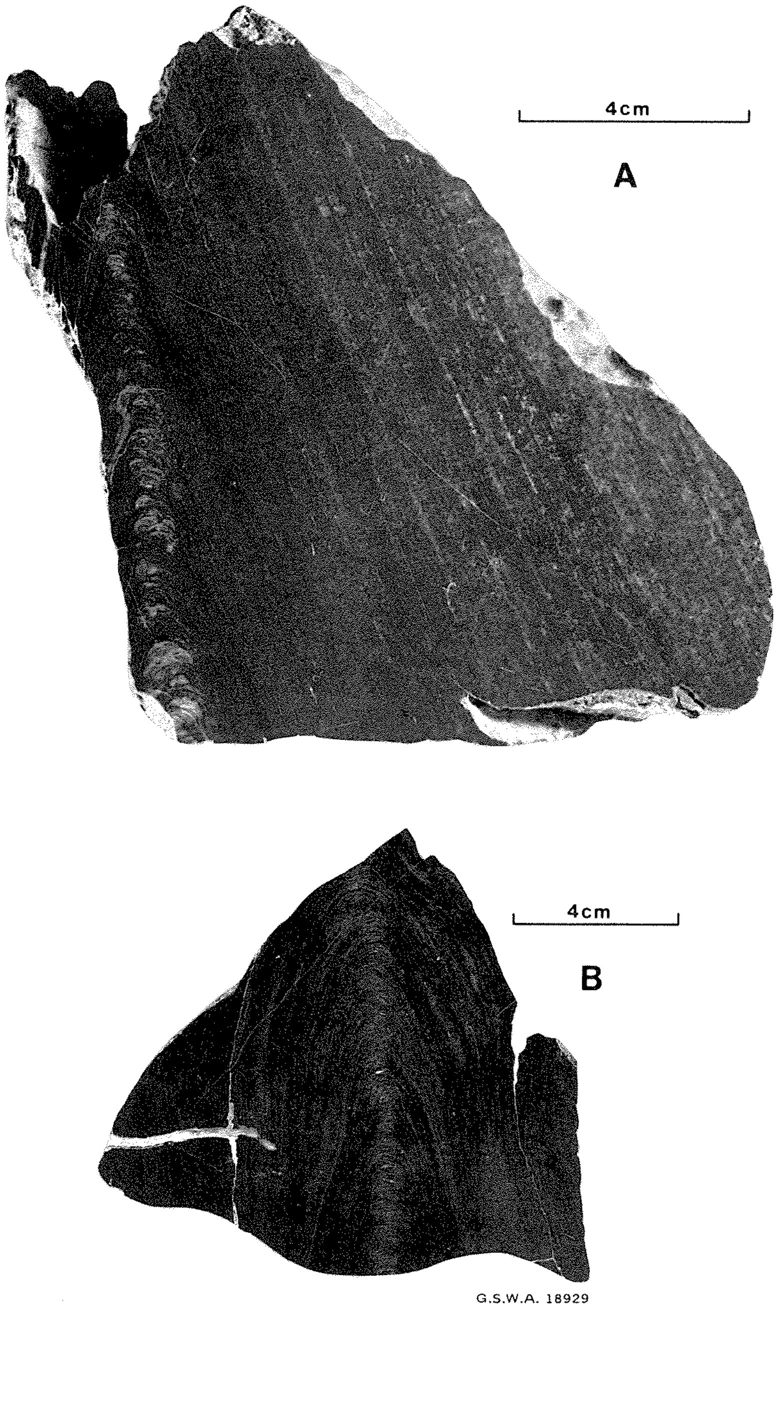


B

G.S.W.A. 18928

Figure 114. *Conophyton garganicum australe* Walter from near Pingandy Creek. A—GSWA F9936. B—GSWA F9935.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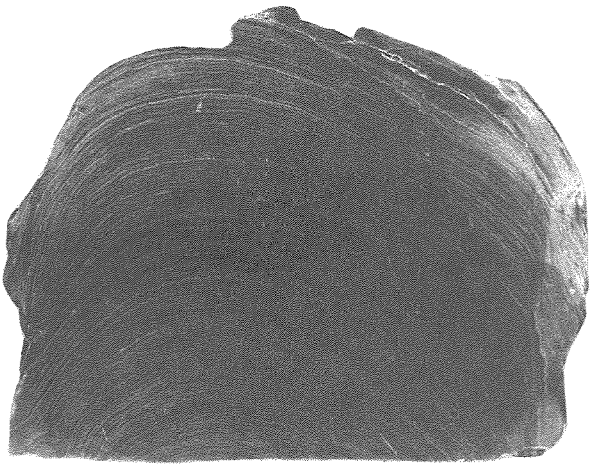
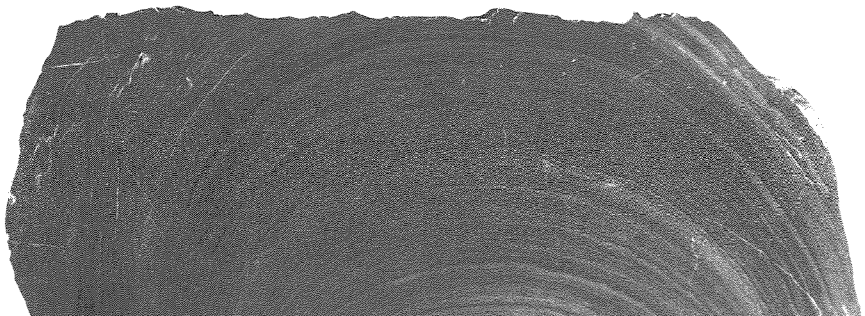
B
G.S.W.A. 18929

Figure 115. Unbranched club-shaped stromatolite (group and form indet.) from Irregully Creek gorge. A—GSWA F9914. B—GSWA F9915.



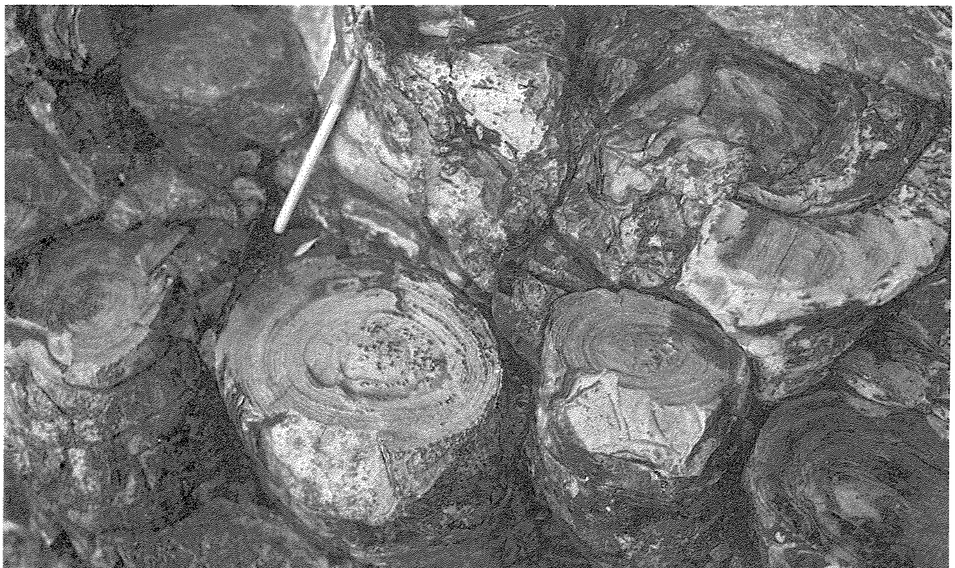
A 4cm



B 4cm G.S.W.A. 18930

Figure 116. Unnamed club-shaped stromatolites in dolomite of the Irregully Formation, Irregully Creek gorge, 63 km north of Wanna homestead. A—Transverse section parallel to bedding. B—Outcrop showing three dimensional shape.

A



B

G.S.W.A. 18931

Figure 117. Microstructure of possible biogenic origin in the Bangemall Group. Bar scale in all figures represents 10 μm. GSWA fossil registration numbers follow description. Co-ordinates on Leitz Ortholux microscope number 587962 are given in brackets.

A—Sphere with radiating concentric structure, Discovery Chert. GSWA F11127 (27.9, -100.0).

B—Trail of diffuse carbonaceous material, Discovery Chert. GSWA F11176 (69.8, -096.8).

C—'Pod' of coarse silica crystals bound by possible organic material, Discovery Chert. GSWA F11140 (41.9, -101.6)

D—Problematic tubular structure showing terminal spheroid, Discovery Chert. GSWA F11143 (41.5, -111.4).

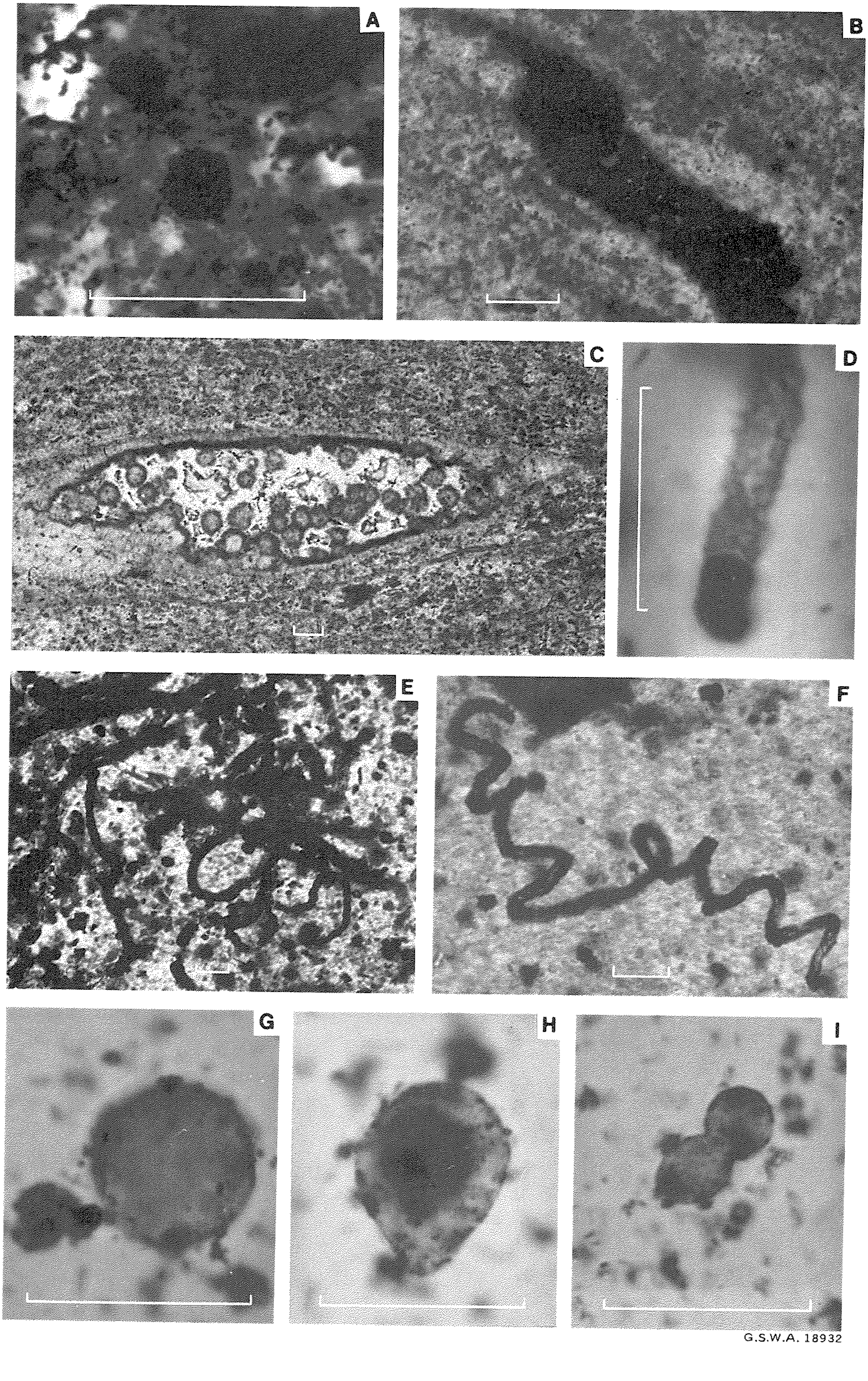
E—Cluster of problematic tubular structures, Discovery Chert. GSWA. F11143 (26.5, -112.3).

F—Problematic tubular structure showing sinuous nature, Discovery Chert. GSWA F11143 (26.3, -105.8).

G—Spheroidal body obtained from maceration, Backdoor Formation. GSWA F11150 (40.9, -114.0).

H—Elongate spheroidal body obtained from maceration, Backdoor Formation. GSWA F11150 (44.9, -114.0).

I—Linked spheres obtained from maceration, Backdoor Formation. GSWA F11150 (52.7, -113.4).



G.S.W.A. 18932